

OBSERVATIONS ON AGGREGATION AND OVERWINTERING IN
THE COCCINELLID BEETLE
COLEOMEGILLA MACULATA (DeGeer)

Allen H. Benton and Andrew J. Crump

Abstract.—In the overwintering site studied, *Coleomegilla maculata* began aggregating in late September to mid-October. The aggregation procedure appeared to be governed by photoperiod rather than temperature.

The major aggregation site studied included three major physical components: large prominent willow trees (*Salix nigra*); a small pond; and a south-facing slope. Migration to this site appeared to occur via a low level flight of positive anemotactic and hygrostatic nature, with the possibility of a hypsotactic component. No chemotaxis was demonstrated, although the possibility was not ruled out.

Once at the aggregation site, beetles remained for some time on the leaves of wild raspberry (*Rubus occidentalis*) and sensitive fern (*Onoclea sensibilis*), especially the dead dry leaves of the latter. It is likely that this resting period on dry leaves assists in the loss of excess water.

Mortality of the beetles in the aggregation was 3% to 9% in the winter of 1973-74. Temperatures within the aggregation were generally higher than ambient temperatures, and the aggregation had a modifying effect on sudden temperature changes which might otherwise exceed the insect's ability to supercool.

Introduction

The massing of Coccinellid beetles for overwintering has been observed in many parts of the world. Aggregations are known to occur only in beetle species with abundant individuals which are closely associated with ephemeral prey or other food supplies which undergo seasonal fluctuation. Such is the case in *Coleomegilla maculata* (DeGeer) which, despite being markedly phytophagous in comparison to closely related coccinellids, aggregates to overwinter. Once the aggregation has been formed, the beetles exhibit a long dormancy period, often existing in below freezing temperatures. Overwintering *C. maculata* enter a state of ateleodiapause (after Mansingh 1971), as the beetles, upon disturbance, are capable of immediate but somewhat sluggish movement. In this state the overwintering adult generation survives for periods up to eight times the normal span of the summer generations.

The behavioral processes involved in migration toward an aggregation site, site selection and the formation of the aggregation vary widely in different species. According to Hagen (1962), *C. maculata* and *Hippodamia convergens* are the only two coccinellid species which do not exhibit simple hypsotactic aggregation. In *C. maculata*, a number of physical factors interact to guide the beetle to its aggregation site, so-called climatotactic aggregation. These factors and their interaction are, in the case of *C. maculata*, poorly understood. This paper reports observations of aggregating *C. maculata* and attempts to illuminate some of the processes used in aggregation site selection and migration.

Location

An aggregation site of *C. maculata* was discovered in 1971 in the town of Pomfret, Chautauqua County, New York. This site has been used each year for at least five years by aggregating beetles and was studied intensively from May 1973 to October 1974, and monitored periodically until May 1976. Unless specifically stated, observations recorded herein refer to this aggregation.

The aggregation was located near a small farm pond encircled by a clump of willow trees (*Salix nigra*), on the south-facing slope of a high bank which had resulted from digging the pond. The bank was generally covered with leaf litter and undergrowth. The area was about 100 meters north of extensive cornfields, and separated from them by a major rail line.

Three other aggregations, two in Erie County, New York and one in Cayuga County, New York, were discovered during the course of the study and were monitored periodically. The Erie County sites were also at the base of large willow trees. The Cayuga County site was at the base of a large poplar (*Populus deltoides*) in the front yard of a farm home and approximately 100 meters west of a large cornfield, and 50 meters north of another cornfield.

Field Observations

In 1973, the first influx of beetles at the aggregation site occurred on October 1, and in 1974 on September 28. These dates were either identical or approximate to arrival dates at the three other sites. Since the 1974 date followed several days of unseasonably hot weather (20°C), we felt that photoperiod rather than temperature was the signal for aggregation. In 1975, however, beetles arrived at the Cayuga County site on October 15, and date of arrival at the main site could not be determined. A few beetles were found on December 1, at a site about ten meters from the major aggregation sites of previous years, so that the exact time of aggregation is unknown. We believe that photoperiod is an important factor in the instigation of

Table 1. Temperatures (°F) at the three sites of overwintering beetles in the aggregation in Town of Pomfret, Chautauqua County, New York, in the winter of 1973-74.

Month	Site 1		Site 2		Site 3*	
	Low	Mean	Low	Mean	Low	Mean
December	27	42	24	37	24	39
January	21	33	22	35	15	31
February	14	39	12	41	8	31
March	20	44	14	42	13	38

* No beetles were present at this site after December.

processes leading to migration and aggregation, although it may not be the prime causal factor.

After the arrival of the first beetles, the aggregation grew rapidly and appeared to be complete within seven days of the initial arrivals. During the initial influx, clusters of beetles were found in depressions in the ground or at the base of saplings around the pond. These sites proved to be transitional, with the beetles eventually joining the main aggregation. The beetles formed three distinct clusters within the aggregation area. The largest of these clusters (site 1) contained the most beetles and was located around the base of the largest willow tree. Site 2 was established in a large depression near the entrance to a woodchuck hole, approximately 5 meters from site 1. The third site (3), containing the smallest number of beetles, was situated on the bank equidistant from sites 1 and 2. During early December the beetles at site 3 migrated to join those at site 1. The final two clusters at sites 1 and 2 covered little more than 0.5 square meters each, both being approximately 3 meters from the pond and elevated 1 meter above the water level. The location of the biggest cluster of beetles (site 1) near the base of the bank and at the base of the largest tree afforded maximum protection from the cold prevailing northerly winds moving in off nearby Lake Erie. At no time during the study were beetles found on the north-facing slope of the bank.

Having migrated to the aggregation site, beetles alighted on the upper sides of the abundant undergrowth species, including wild raspberry (*Rubus occidentalis*). Soon after arrival the beetles congregated on the undersides of the leaves and particularly under or in dead, dry, rolled up leaves of the sensitive fern (*Onoclea sensibilis*). Beetles on the undersides of leaves were generally immobile, while those on the upper surfaces (presumably newer arrivals) were more active. This pattern of arrival and subsequent association with dead vegetation was apparent throughout the aggregation formation. The reason for this is unclear but may be connected with the need to lose excess water, the freezing of which is thought to be the cause of some mortality among overwintering beetles (Hodson, 1937).

While in this situation, the beetles show a definite thermokinesis. Warmer periods induced greater activity but the beetles remained at the same levels on the vegetation. The thermokinetic response is, however, clearly complexed with other tactic responses as drops in temperature served to accelerate or instigate movement to the ground. Once on the ground, the beetles huddled under the top layers of loose soil and dead and decaying vegetation, where they remained for the duration of the winter.

Mortality

Maximum-minimum thermometers were placed among the three original aggregating groups of beetles at sites 1, 2, and 3. The thermometer at site 3 was left in place after the migration of the beetles to site 1. Sudden drops in temperature, thereby not giving the beetles sufficient time to supercool, are known to be the major cause of death in overwintering beetles (Hodson, 1937). During the winter of 1973-74, the temperatures never dropped below the level to which *C. maculata* can supercool successfully. Temperatures taken during the winter months (Table 1) show two main points. First, the "low" temperatures at sites 1 and 2 were higher than those at the beetleless site 3. Second, and more important, the "low" temperatures at site 2 were usually lower than those at site 1. This indicates the importance of the greater number of beetles at site 1 helping to maintain a higher temperature within the aggregation.

Actual mortality was determined by taking groups of beetles from the aggregation, placing them in wire mesh containers which afforded little extra protection, and replacing them in their original aggregation. At the end of the winter, mortality figures of 3% for site 1 and 9% for site 2 were obtained. In addition to the greater number of beetles at site 1, most of the beetles at this site were shielded from northwesterly winds by the presence of the willow tree whereas those at site 2 were not. This, together with the lower number of beetles, may account for the higher level of mortality observed at the more exposed site 2.

Discussion

The mechanisms and responses involved in triggering aggregation and in the migration to the aggregation site are difficult to elucidate due to their complex interactions. The possibility of a chemical cue being utilized in the selection of the aggregation site cannot be dismissed. Weiss (1913) felt that odor was important as an attractant to the aggregation site. However, during olfactory tests carried out on *C. maculata* no chemotaxis was found, the only consistent positive response being towards moisture-laden air. Landis (1936) showed that there is a significant difference in the reassociation of the Malpighian tubules in climatotactic as opposed to hypsotactically ag-

gregating species. Hodson (1937) also indicated that *C. maculata* showed a marked preference for specific moisture situations, suggesting that these were significant in reducing the effect of cooling by the latent heat properties of water. *C. maculata* is known to be very susceptible to desiccation and the ability of the beetle to detect and move towards moisture-laden air has been shown to affect its distribution in its summer habitat (Crump and Benton, in prep.). Adult *C. maculata* are larger and heavier than other closely related Coccinellids, including *H. convergens* which also undergoes climatotactic aggregation. The larger size, in conjunction with the predilection for moist areas and its profoundly pollenaceous diet, causes the low level flights and low distribution of *C. maculata* in vegetation (Ewert and Chiang, 1966). Short, low-level migratory flights would explain why many aggregations are found at or near the edges of open fields. Migration to the aggregation site is determined by positive hygrotactic and anemotactic responses complexed with a hypsotactic component causing aggregation at the bases of prominent objects in an area of optimum moisture level.

Aggregation of *C. maculata* serves as a method of enhancing winter survival, there being two aspects to this enhancement. First, the large number of beetles present emphasizes the aposematic coloration of the beetle. Second, and more significant, large numbers of beetles provide a degree of heat conservation. These factors combined with the biochemical mechanisms involved in the ateleodiapause of *C. maculata* ensure a greater survival rate over the arduous winter months.

Acknowledgments

This research was supported by National Science Foundation grant B036435. For assistance with field work, we are indebted to James Moore and Richard Northrup.

Literature Cited

- Balduf, W. V. 1935. The bionomics of entomophagous Coleoptera. J. S. Swift Co., Inc., St. Louis.
- Crump, A. J. and A. H. Benton. In prep. Observations on spring and summer behavior in *Coleomegilla maculata* (DeGeer).
- Ewert, M. A. and H. C. Chiang. 1966. Dispersal of three Coccinellids in a corn field. *Canad. Entomol.*, 98:999-1003.
- Hagen, K. S. 1962. Biology and ecology of predaceous Coccinellidae. *Annual Rev. Entomol.*, 7:289-326.
- Hodson, A. C. 1937. Some aspects of the role of water in insect hibernation. *Ecol. Monographs*, 7:271-315.
- Landis, B. J. 1936. Alimentary canal and Malpighian tubules of *Ceratomegilla fuscilabris* (Muls.). *Ann. Entomol. Soc. Amer.*, 29:15-28.

- Mansingh, A. 1971. Physiological classification of insect dormancies. *Canad. Entomol.*, 103:983-1009.
- Weiss, H. B. 1913. Some tropic reactions of *Megilla maculata* (DeGeer). *Canad. Entomol.*, 45:85-87.

Department of Biology, State University College, Fredonia, New York 14063.

Received for publication December 14, 1978.